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Vibration Characteristics of Ultrasonic Complex Vibration Source Using Transmission Rod with Different Cross-Sectional Area

異なる断面積を有する伝送棒を用いた超音波複合振動源の振動特性

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1. Introduction

Conventional ultrasonic welding often uses only linear vibrations, which causes problems including insufficient welding strength. To develop vibration sources that generate longitudinal-torsional complex vibrations, we have investigated how planar vibration improves the welding strength when an exponential horn and a transmission rod with the same cross-sectional area are used as a vibration source and driven simultaneously at the resonance frequencies of longitudinal and torsional vibration[1,2].

In this paper, a single longitudinal vibration transducer, an exponential horn, a short rod, and a transmission rod with a different cross-sectional area were used to generate complex vibrations driven by a single frequency by bringing the longitudinal and torsional vibration resonance frequencies closer together. The short rod was used to adjust the resonance frequency and was attached to the transmission rod. The vibration characteristics of the ultrasonic complex vibration source, which created torsional vibration with a helical slit in the transmission rod, were investigated.

2. Ultrasonic complex vibration source

Figure 1 shows a schematic of the ultrasonic complex vibration source used in the study. The vibration source consisted of a 39 kHz bolt-clamped Langevin longitudinal vibration transducer (Honda Electronics, HEC-3039P4B), an exponential horn with flange (material, A2017; diameter of narrow-end face, 10 mm; diameter of thick end face, 30 mm; amplitude expansion ratio, 3), a short rod for resonance frequency adjustment (material, SUS303; diameter, 10 mm; length, described later), and a transmission rod (material, SUS303; diameter, 12 mm; length, 52–62 mm), which were screwed together. The side of the transmission rod had a helical slit with a semicircular cross-section 3.5 mm deep, a rotation speed of 1, and two bars.

The longitudinal vibration is in the direction of the central axis in Fig. 1, the torsional vibration is in the circumferential direction, and the flexural vibration is in the direction perpendicular to the central axis.

3. Longitudinal and torsional vibration resonance frequencies

The change in the frequency of the

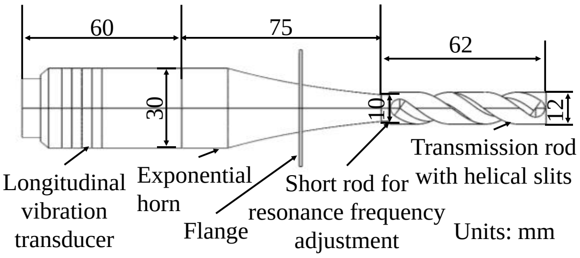

Fig. 1. Schematic of the ultrasonic complex vibration source.

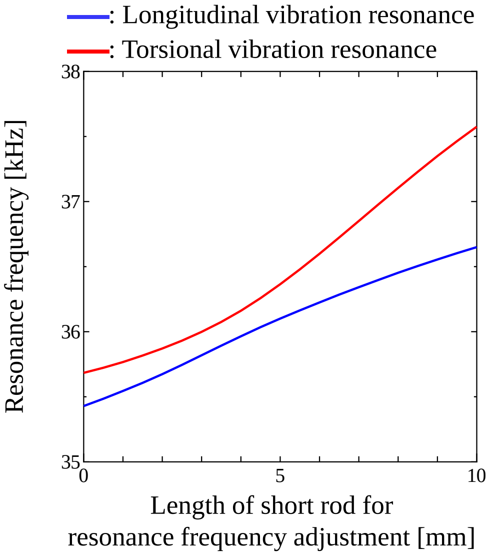

Fig. 2. Resonance frequency characteristics of the ultrasonic complex vibration source.

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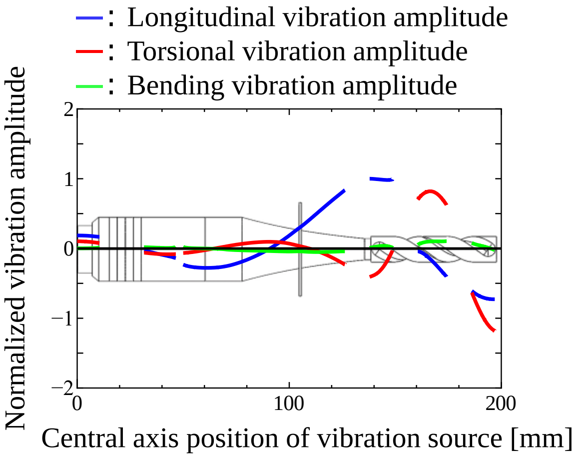
longitudinal and torsional vibration resonance was examined as an indicator for the coupling of the vibration modes of the longitudinal and torsional vibration. Piezoelectric modal analysis of the longitudinal and torsional resonance frequencies of the ultrasonic complex vibration source was performed by varying the length of the short rod to adjust the resonance frequency from 0 to 10 mm. The analysis model was the same as in Fig. 1. The total length of the short rod for adjusting the resonance frequency and the transmission rod was kept constant at 62 mm.

Figure 2 shows the results. The horizontal axis shows the length of the short rod for resonance frequency adjustment, and the vertical axis shows the resonance frequency. The blue line in the figure shows the frequency at the longitudinal vibration resonance, and the red line shows the frequency at the torsional vibration resonance. The frequencies of the torsional and longitudinal vibration resonances increased with the length of the short rod. The frequencies of the longitudinal and torsional vibration resonances were closest when the length of the short rod was 3 mm. In the following discussion, the length of the short rod was set to 3 mm where the vibration modes were coupled.

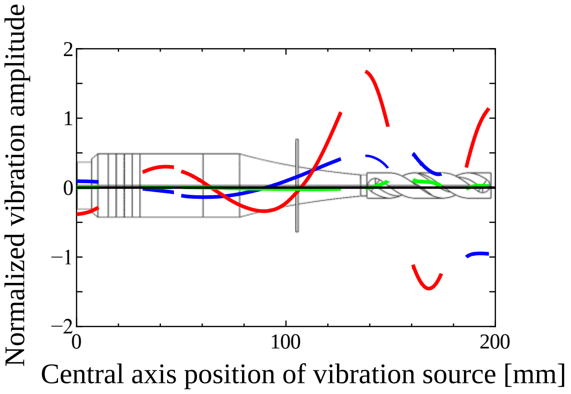
4. Vibration distribution of the complex vibration source

The vibration distribution of the longitudinal, torsional, and flexural vibrations of the vibration source were investigated by piezoelectric modal analysis. The analytical model was the same as in Fig. 1. **Figures 3**(a) and (b) show the vibration distribution of each vibration at the longitudinal and torsional resonance frequencies of 35.82 and 35.93 kHz, respectively. The horizontal axis shows the position of the central axis of the complex vibration source and the vertical axis shows the amplitudes of the longitudinal, torsional, and flexural vibrations normalized by the maximum amplitude of the corresponding longitudinal vibration amplitudes. The blue, red, and green lines show the amplitudes of the longitudinal, torsional, and flexural vibrations, respectively.

Both figures show that the amplitude of the longitudinal and torsional vibrations peaked at the tip of the transmission rod of the ultrasonic complex vibration source for both resonance frequencies. The complex vibration was obtained at both longitudinal and torsional resonance frequencies, indicating that the vibration modes were coupled. Furthermore, flexural vibration was not achieved.



(a) Longitudinal vibration resonance frequency (35.82 kHz).



(b) Torsional vibration resonance frequency (35.93 kHz).

Fig. 3. Each vibration distributions.

5. Conclusion

The vibration characteristics of an ultrasonic complex vibration source with an exponential horn and transmission rod with different cross-sectional areas were investigated. The frequencies of the longitudinal and torsional vibration resonances increased as the length of the short rod for adjusting the resonance frequency increased. The amplitude distributions of the longitudinal and torsional vibrations at the resonance frequencies of the vibration sources showed that both vibrations almost peaked at the tip of the transmission rod.

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References

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